

DISCUSSION BEFORE THE WIRELESS SECTION, 6TH MARCH, 1940

Mr. P. P. Eckersley: The author's statement that only about 3 % of the total number of British listeners receive their programmes by wire may be misleading. Had the position of the rediffusion companies been more clearly defined throughout the development of wire broadcasting that figure would have been considerably increased, perhaps to the figure of 50 % which has been reached in Holland.

Broadly speaking, the paper is a statement of the various methods by which a wire broadcasting system can be consummated. There is no question that the audio system, with a buried network, is the best technical method; it gives better quality and greater reliability than the other methods but it is impracticable as it means digging up the streets to lay the network. The overhead audio system may introduce frequency-characteristic distortions, and I suggest that the author should include in his list of References a paper dealing with this question which I read before the Wireless Section in 1934.* The combination of the inductance of the open-wire leads and the capacitance of the down leads causes some rather violent distortions unless precautions are taken to terminate the feeders with resistance.

The carrier systems which make use of the supply mains have as their chief advantage over those which rely on telephone wires the fact that the mains go into 5 times as many houses as the telephone. Nevertheless, from a purely technical point of view, it is easier to use the telephone than the mains network. But if both are practicable and both economic and one has a wider application, it should be used wherever possible.

In costing the telephone system the expense of writing off the associated wireless receiver presumably has to be added to the weekly charge for the service. I should like the author to tell us how much the charge would be with the extended wiring system. To this must be added the charge for the telephone. If the telephone were installed in order to make the wire broadcasting service available then some charge should be added.

In the scheme we devised, using the mains network, we found it better to employ much lower frequencies than those used by the author in his experiments. We furthermore devised a method of distribution in which the load variations did not vary the signal level. We found that, using special methods of distribution and lower frequencies, the necessary power per consumer was 2 mW, not 16 mW as found in the author's experiments. We provided a "selector" which when plugged into the mains gave four or six alternative programmes; we never planned to use an ordinary wireless receiver with its greater complication and often mediocre performance.

Turning to the problem of the bridging of transformers, it was found in some experiments which were made in America, where high-frequency currents were passed through the transformers and where the domestic load was energized by the high-frequency currents, that when any device the high-frequency impedance of which varied in sympathy with the power currents was connected across

the mains, the superimposed currents were modulated in intensity at the frequency of the power currents. In other words, "hum modulations" were created.

We do not require either to strap transformers or to pass high-frequency currents through them, because in British practice there are far more consumers connected to the secondary of a single transformer than in American mains layout. This fact makes it economic with British networks to energize each secondary network from separate repeaters. A conductor carrying the output of all the transmitters interconnects the substations and energizes the repeaters.

The author rightly says that one of the chief difficulties of the mains system is the extremely low surge impedance of the network. There is furthermore the point that unterminated feeders can have an actual impedance lower than their surge impedance. In certain substations, 10 feeders may be brought together, giving actual impedances of the order 0.1 or 0.2 ohm. The difficulty of designing feeders and transformers to feed high-frequency currents into such networks is considerable; we have overcome our problems more by careful design than by any special devices.

We believe that our mains system is ubiquitous, economical and practicable, but I fully agree that the telephone network system has many advantages. It would appear the wisest to combine all and any systems so that each is used according to its suitability for a given set of conditions.

Mr. W. West: I am impressed by the potentiality of the audio-frequency system for supplying a uniformly high-quality service. The controls which the subscriber has to operate are such that at no possible setting can the distortions exceed the small tolerances to which the system as a whole has been designed. The volume control, for example, is limited to a variation of ± 10 db. from the level which is selected as normal; this avoids the fault (not uncommon among listeners to radio programmes) of turning up the volume to such a stentorian level that not only are most of the sounds too unnaturally loud but also severe distortion is being introduced by the amplifier. The limitation of the volume level is in my opinion a definite asset, and it has the incidental advantage of reducing the possibility of the noise nuisance to neighbours. The comparative immunity of the audio-frequency system from noise interference has been mentioned by the author; another valuable feature, from the point of view of programme quality, is that the power amplifier is continuously under skilled maintenance. With other systems for receiving broadcast programmes the amplifier is at the listener's premises and subject to maintenance at his own discretion. The gradual deterioration of the valves over a period of months, or years, causes an insidious degradation of quality to which no attention may be given before the condition has become chronic. If, in addition, the service were supplied by an organization which is able to obtain all its equipment on the basis of acceptance tests to a high-grade performance specification, listeners would have access to a higher standard of quality of reception of broadcast programmes than is now available, and at a cost which

* *Journal I.E.E.*, 1934, **75**, p. 333, and *Proceedings of the Wireless Section*, 1934, **9**, p. 230.

the author has calculated to be comparable with that which is ordinarily paid.

I am interested in the manner in which the levels available on the subscriber's volume control were selected, and perhaps the author can give some further information. At the normal (i.e. the middle) setting, is the loudness of the announcer's voice approximately the same as would be used by a person in the room when speaking in general conversation to people in the room who are not otherwise engaged in conversation?

In connection with the design of the loud-speaker, the author mentions that an axial sound-pressure characteristic rising at a rate of 2.5 db. per octave is required. To avoid possible misunderstanding, I take this opportunity to mention that this rule is not suggested for universal application to loud-speaker design. It is derived from the finding that, for the average listening position in a living room, the reverberant sound predominates over the direct sound. From this it was deduced that a uniform frequency-characteristic of total sound power radiated is required from the loud-speaker, and it was found that, with the particular type of loud-speaker which the author has described, uniform total power corresponds very closely with a rising characteristic for axial sound-pressure at 2.5 db. per octave. The axial sound-pressure is the more convenient practical criterion of performance, since the measurement is more simple and direct.

Dr. R. L. Smith-Rose: In view of Mr. Eckersley's remarks in favour of the dissemination of music and speech by wire, it is interesting to ask why he did not introduce wire broadcasting following his early experiments at Writtle, and so forestall the introduction of wireless broadcasting. If Mr. Eckersley had been born a little earlier and had been chief engineer of the Electrophone Company in 1895, the B.B.C. might possibly never have existed. The fact is, of course, that although those early experiments did show the possibility of distributing programmes over wires, they were a little before their time, and it was not until after the introduction of wireless broadcasting that there were developed the technical apparatus and equipment which have made the re-establishment of wire broadcasting at all feasible.

I should like the author to explain how the difficulty of interference has been overcome in the use of apparatus connected either to the power mains or to the telephone line. My experience is that telephone lines are not as free from interference as is a good broadcasting receiver at the present time. One of the most serious sources of disturbance in a radio receiver is the interference which is conveyed along the electric supply mains, and fed into the receiver either by conduction or by radiation from neighbouring mains. It would seem that when the whole of the programme was taken from the mains there would have been still greater difficulty, and I should be interested to know how this has been overcome.

The use of a radio receiver in conjunction with wire broadcasting surely introduces an additional source of interference, namely direct reception of broadcasting on the receiver itself, and I should like to ask how this has been eliminated. In the author's demonstration receiver the screening seems to have received considerably more

attention than is customary with ordinary commercial receivers.

Mr. F. L. Coombs: I agree with Mr. Eckersley that the author's statement that only 3% of the total number of British listeners receive their programmes by wire is rather misleading. In areas where wire broadcasting is available, the proportion of licence-holders receiving this type of broadcast is nearer 33½%, and in one town of 8 000 houses where a wire broadcasting system operates there are more than 4 000 subscribers.

I should like to know whether the author has carried out any research into the broadcasting of high-frequency signals over the networks of audio systems which are now in existence. These networks are not subject to the same difficulties as the mains from the point of view of transformers at the distribution substations, and they have a considerably higher characteristic impedance. If it were found possible to transmit high-frequency signals over these networks the listener could be given a choice between the audio method and the high-frequency method. While the high-frequency method is more advantageous from the point of view of the number of programmes which can be disseminated, the audio system is preferred by the subscriber who wants the minimum of apparatus in his home.

Dr. L. E. C. Hughes: There is no real competition between broadcasting over power mains and over telephone circuits, provided the same service is given by each. Both types ought to be developed along reasonable commercial lines, because technically both offer substantially the same grade of reproduction and number of channels. One cannot regard the push-button receiver demonstrated by the author as representing a satisfactory standard of reproduction, because a standard of reproduction clearly implies a definition which complies with the well-known criteria for faithful reproduction, in this case applying to a single channel. Moreover, the quality obtainable with such mass-produced receiving sets is very variable, and does not improve as time goes on. A standard of radiated reproduction has not yet been defined by an authoritative body, but I would suggest to the author that the reproduction obtained with the non-modulated system over telephone lines might reasonably be taken as a good sample of what can be attained in reproduction nowadays. The public would then be able to judge the value of reproduction from other types of receiving apparatus if they had this reference easily available. In making the reproducers on a large scale, the average quality of reproduction must inevitably be somewhat less than is obtainable in a laboratory-constructed equipment; how is the tolerance of departure from the reference to be determined, and by whom assessed?

Mr. A. J. Gill: I think the title "Wire Broadcasting" is rather inappropriate, because with this system the programme is not distributed anywhere and everywhere but is sent exactly where it is wanted.

I notice that the author made some tests using oil-impregnated paper cables, and it would be interesting to know whether he considered making tests with the ordinary dry paper cable used for telephonic purposes. Where oil-impregnated paper cables are used it is usually necessary to seal the ends so that leakage of oil is pre-

vented; perhaps he would explain how sealing is obviated in this case.

The fact that only 3 % of the listeners in this country receive their programmes by wire may be due partly to the uncertainty of the position which has prevailed up to now, and partly to the fact that in some cases the local authorities have opposed the introduction of wire broadcasting. There is some objection to an additional authority opening the streets in order to lay cables, and there is a good deal to be said either for incorporating the wire broadcasting in the Post Office telephone system or for the supply authorities using their cables for the purpose.

Dr. Smith-Rose mentioned the possibility of direct radio interference on receivers, and the consequent need for screening. I take it that the band used here is the long-wave band, however, and that the noise level is relatively high so that a small amount of radiation from the line system would be unnoticed. As for the absence of noise, which Dr. Smith-Rose finds surprising, the noise limit which we try to set on telephone trunk lines is about 55 db. below ordinary speech value, so that when there is anything else on the line the noise should not be noticed. The noise is mostly of audio frequency, and therefore there would be little or no trouble at the carrier frequencies. In electrical laboratories and works induced noise may be present, but this is not usually the case in residential areas where a wire broadcasting system would be used.

Mr. H. B. Rantzen: An important factor in programme reception by any means is the motive which prompts the listener to receive a particular programme—whether, for example, it is a desire to exercise his skill in handling his receiver or merely his wish to be entertained. Most of the wire systems which have been constructed so far have been presented as a complete alternative to radio reception, very largely in areas where a satisfactory wireless signal is not available. As far as the Post Office carrier system is concerned, I think that not many people can be expected to install a system in which four programmes coming in by line can be received only by having a complete wireless set. It seems a pity that the good signal-strength obtainable by line should have to go through the high-frequency side of commercial sets, many of which are designed almost like communication receivers in this respect.

I think the economics of the system, and possibly the method of distribution, might have been very different if the number of programmes had been reduced to two. In these circumstances, low-frequency distribution of the programme might prove economical. This might also have led to the development of sets in two parts: a very selective high-frequency stage, followed by a high-quality low-frequency receiver. The complete set must be available either for distant listening or for high-quality home reception. Generally speaking, so far, there have not been more than two programmes available for home listening.

Fig. 19 shows a distribution system which is partly audio-frequency and partly carrier-frequency. I should be glad if the author would tell us at what levels he feeds the two types of signals to line, and what sending impedances he uses. It seems to me that in some cases there

will be difficulties in providing the necessary power to be fed into very low impedances. What is the proper input-voltage level to his 15 000-ohm loud-speaker?

Seeing that the paper deals with so many complicated line transmission problems it contains surprisingly few references to cross-talk. It has been my experience that when dealing with lines alone, from terminal to terminal, one can often expect a signal/noise ratio of about 90 db. But as soon as exchange apparatus is installed at the terminal, the figure comes down to about 50 db.

Referring to Fig. 4, I notice that the protective equipment has been left in the lines in the programme circuit, and I should like to know whether this gives rise to any difficulties. In dealing with outside broadcasts we try to reduce the protective equipment to a minimum.

If in a cable there are 20–30 pairs all carrying carrier frequencies with their programme modulations on them, the cross-talk may be sufficient to ensure that the carrier is on every pair in that cable. In high-frequency work on local telephone cables we found that low levels of very high-frequency energy travelled down the cable, apparently between the centre of the cable and the lead sheath.

I should be glad if the author would confirm that he has always found it necessary to connect up to every pair in the cable that has to be fed with programme.

Mr. G. C. Marris: The quality of the reproduction is one of the factors which will decide the success of a wire broadcasting system. Another factor is the quality of the standard broadcast receivers and loud-speakers which are available.

Despite the remarks of Dr. Hughes the fact is that, judged by performance curves, by power output, by freedom from harmonics and by reports from skilled listeners, the quality of reproduction given by radio receivers has been improved rapidly in the last few years.

I should like to ask the author what power per loud-speaker he thinks is a usual figure on audio systems.

Mr. E. M. Lee: I should like to make a few remarks on the subject of the suppression of interference. I have been trying for a number of years to persuade the public to pay just a little to have their interference cured; but I find that they always want it cured for nothing, and I am very pessimistic about their paying even 1s. a week to get interference-free reception. I am afraid that so many of the best Post Office technicians may concentrate their attention on the wire broadcasting system that they will be unable to push through the legislation at which we have been aiming for years to compel the suppression of interference from electrical appliances.

Mr. W. A. C. Maskell: When considering the justification for a wire broadcasting system in comparison with other systems of reception such as radio receivers there are three points which have to be borne in mind. The first is the strategic angle (in time of war), the second the economic angle and the third the necessity of providing what the public want with regard to reproduction.

The economic question is bound up with the price at which the Post Office can offer its service to the public. The listener has to consider whether the alleged better quality and limited number of stations given by wire

broadcasting for, say, 1s. 3d. a week is more valuable than all one can get on a radio set to-day with long, medium and short waves.

As regards the third point, which is really the question of quality, in the author's demonstration we have heard the engineer's conception of quality. From a considerable amount of experience I am prepared to say that that is not what the public as a whole require, and the question is whether we set out to educate the public to the engineer's standard or let them judge for themselves.

We can reproduce speech at roughly the same value as that at which it was delivered and get an excellent equivalent to the original, but music is a different problem and must of necessity be a compromise. I think, therefore, that the failure to provide any form of variable tone balance on the Post Office equipment is a great mistake.

[The author's reply to this discussion will be found on page 140.]

DISCUSSION BEFORE THE MERSEY AND NORTH WALES (LIVERPOOL) CENTRE, AT LIVERPOOL, 15TH JANUARY, 1940

Prof. E. W. Marchant: One of the first wire broadcasts of music occurred in about 1897, when the late Mr. Duddell, who was experimenting at the City and Guilds College with the oscillating arc, made up a keyboard with which it was possible to play a tune. The electric oscillations from the arc were transmitted along the street mains, with the result that passers-by in Exhibition Road heard, to their amazement, the tune of "God Save the King" coming from the street arc lamps; and I believe the same effect was observed in one of the lecture rooms of the Royal College of Science, where an arc lamp was being used for a lantern.

It is surprising to learn that, in Holland, over 50 % of the listeners use wire distribution. The difficulty in connection with a wire broadcast is that the cable system requires maintenance and a relatively heavy capital expenditure. Technically there is no serious difficulty in regard to the transmission, provided there is uniform attenuation in the cables at all frequencies. The problem is the same as that of a telephone transmission, and for good results special cables must be employed. It is quite evident that an ordinary cable such as is used for power transmission has not the same characteristics as those required for a telephone transmission. On general grounds, therefore, there seems no doubt that the attempt to use a power-cable network for broadcast programmes is a retrograde step. It is worth while also to compare the cost of a two-programme service by wire broadcasting relay companies with the cost of radio transmission. The broadcasting relay service costs 1s. 6d. a week or £3 18s. a year, as compared with the 10s. paid for a wireless broadcast license; but for this latter payment and the maintenance costs set out in the paper an almost unlimited range of programmes is available. As regards the relative effectiveness of wire broadcasting at audio frequencies and at carrier frequencies, I think there is no doubt that the carrier is the more efficient, in just the same way as modern carrier systems of telephony have proved themselves much more efficient than audio-frequency circuits. The layout of the wire broadcasting stations is very similar to that of an ordinary telephone system, and the paper describes the complications involved in this system of transmission as compared with a radio system. It is rather significant also to see that, apart from the present paper, all the literature dealing with this subject is of German origin. I think, therefore, that, although the paper has technical interest, it is not likely to prove of any great practical utility in this country. A further disadvantage of wire broadcasting

is that in the event of damage being done to the cable network a much larger number of subscribers are likely to be put out of action than would be the case if they were all using wireless sets.

A point also which is of some importance is that the strength of the signal received by different subscribers to a wire broadcasting system will be very different at different distances from the distribution centre, and that if they are to give the best results the receivers require individual adjustment, just like broadcast receivers.

May I suggest that it would be an advantage to avoid using the neper, which is now a defunct unit, and give all attenuations in decibels.

Mr. F. Mercer: The use of impregnated cable has certain advantages from a maintenance point of view but results in cables with higher attenuation.

Would it not be more satisfactory for the main feeder and for the distribution cables to be of the dry-core air-space paper-insulated type? The service cables, i.e. those leading directly into the listener's premises, could usefully be of the impregnated type, but would have little effect on the overall loss. Such an arrangement would be more efficient. There would also be a smaller difference in level between the upper and lower frequency limits, with consequent improved quality.

Mr. E. Blackburn: Some 6 or 7 years ago I was engaged on measuring the propagation characteristics of overhead trunk lines between 40 and 200 kc./s. One important point which emerged was the high value of the reflection losses which occurred at each change of gauge. The lines tested had a number of power crossings where the telephone lines were taken underground for a section of 100 yd. or so, and the losses at these points were so large that we had to design special matching transformers to obviate them.

The average telephone subscriber in a provincial suburban area has an underground-cable pair which has several changes of gauge of wire, and his line ends in one or more spares of open wire; I should therefore imagine that the reflection losses at the various changes of impedance characteristic will at least equal the line attenuation.

It appears to be the intention in the case of the carrier system to allow the use of the subscriber's radio set as part of the circuit. There are certain difficulties which have no doubt been taken into account. If an obscure or intermittent fault develops there will be need for the Post Office man and the radio service man to co-operate, and delay may result; also, if the receiving set is of

poor quality, the subscriber may get a bad impression of the Post Office service.

I am rather surprised that the loud-speaker chosen for the work should have an output characteristic rising by as much as 2.5 db. per octave. From my own observa-

tions, most sets having a tone control are worked with a bias in favour of the low notes, and I think it would be wiser to provide a speaker of level response with a tone control to enable the subscriber to satisfy his own tastes and conditions.

THE AUTHOR'S REPLY TO THE DISCUSSIONS

Dr. T. Walmsley (*in reply*): I agree with Mr. Eckersley that had conditions been different the number of listeners who received their programmes by wire in this country would have been more than 3 %. However, I am not sufficiently optimistic to believe that the figure would have reached 50 %.

The difficulties of introducing a buried network are realized, but it should not be forgotten that there is already in existence in this country a very extensive system of ducts that could be used for the purpose.

With regard to Mr. Eckersley's claim that electric supply mains go into 5 times as many houses as the telephone, it is pointed out in the paper that lines can easily be extended from telephone subscribers' circuits to non-telephone subscribers' premises. The additional expenditure required is not great but I am not at liberty to give any figures in this connection.

It is interesting to note that Mr. Eckersley found that, using special methods of distribution at lower frequencies, the necessary power per consumer was only 2 mW. This is very much larger than that required by receivers connected to a telephone system. Moreover, it is certain that in some areas where interference from power plant is severe 2 mW would be inadequate. The selector mentioned by him must necessarily be a radio receiver designed for a particular application.

Mr. Eckersley's statement, that it is more economical to energize each secondary network from separate repeaters, leads inevitably to the conclusion that with the type of distribution system in general operation in Great Britain a very large number of repeaters would be required. This contrasts very unfavourably with the requirements in a system utilizing a telephone network, where one local amplifier can provide for the needs of an area having a radius of approximately 2 miles. In the same area using the electric supply mains some dozens of amplifiers would be necessary. Furthermore, a secondary wire network would have to be provided to feed the programmes to the repeaters.

Mr. Eckersley stresses the difficulties due to low surge impedance of the electric supply network. It would be interesting to know how the difficulties have been overcome by careful design rather than by special devices.

Mr. West's remark, regarding the manner in which the levels available on the subscriber's volume control are fixed, presumably refers to the audio-frequency system. It will be appreciated that in this system distant subscribers will have a level several decibels lower than near subscribers. It is correct to assume that the normal setting of the volume control gives the loudness of the announcer's voice approximately the same as would be heard by a person in the room when joining in general conversation. In deciding the various levels, the opinions of a number of people were ascertained. The lowest level was such as to give a background of music

such as not to prevent conversation, whilst the higher level satisfied a listener desiring somewhat strident sounds.

Dr. Smith-Rose asks how the difficulty of interference has been overcome in the use of apparatus connected either to power mains or to telephone lines. Two methods can be used for this purpose. The first is to render the carrier level so high as to overcome all interference effects. The second is to introduce high-frequency filters so as to reduce the noise within the band required by the receiver. In practice a compromise between these two methods is arranged, as far as the carrier over telephone wires is concerned. As already explained in the paper, the introduction of small filters presents no difficulties. In the case of distribution over power mains, however, the problem is much more difficult and generally a high carrier level is required. To ensure that direct reception of radio broadcasting stations is obviated, carrier frequencies are so chosen as to avoid interference from those broadcasting stations giving a high field strength in the locality concerned. Moreover, where an entirely underground telephone system is employed the field strength of interfering stations at the receiver is usually very weak.

In reply to Mr. Coombs, I have not carried out any research into broadcasting on high-frequency signals over open-wire networks of audio systems now in existence. Such a method of distribution is technically possible, although it is very doubtful whether it will yield any economic advantage.

I do not agree with Dr. Hughes that both types of broadcasting, viz. over power mains and over telephone circuits, offer substantially the same grade of reproduction, if he implies this is under similar technical conditions. My conviction is that, owing to the greater variation in noise and its higher average level, the electric supply system does not offer the same advantages as the telephone system.

Mr. Gill raises the question of the title "Wire Broadcasting" and points out that the term is inappropriate because with this system the programme is not distributed anywhere and everywhere. In our misguided optimistic days this is exactly what we hoped to do—hence the justification for the term!

The necessity for sealing oil-impregnated cables depends essentially upon the extent of the impregnation. The type of cable chosen was such that there was no leakage of oil from the ends, thus obviating the necessity for sealing. However, arrangements were made in each subscriber's premises to cover with a suitable compound the ends of the leading-in pairs where they entered the subscriber's connecting box.

I am inclined to agree with Mr. Rantzen that the weakness of any carrier system is that a complete wireless set is required at the receiving end. It should, however, be pointed out that a simplified form of set giving

better reproduction than that normally obtainable from a radio receiver is possible with a carrier system.

The levels at which signals are fed into the lines in a carrier system having transmitters connected to Post Office lines are as follows: Audio frequencies, single-level programme, 10 db. above 1 mW into 600 ohms, the programme level being adjusted so that peaks do not exceed this value. The carrier frequencies in junction circuits are fed at a level of 1 watt per unmodulated carrier into 150 ohms, and into the subscriber-circuit busbars at a level of 0.3 volt. The subscribers receive approximately 10 mV, adjustment being made at the exchange end of the line by means of coupling condensers so that this level is attained.

With regard to the 15 000-ohm loud-speakers used on the audio system, the voltage at the listener's end of the feeder was of the order of 85 volts. The experience of Mr. Rantzen when dealing with lines is somewhat unfortunate. It is agreed, however, that even though the cables themselves are quite good, end conditions can degrade the balance considerably.

I agree that the existence of protective equipment is a potential source of trouble. The cross-talk between pairs in the same cable is a variable quantity, but is very dependent on terminal conditions. Tests were made in the early days to ascertain whether it would be possible to feed by means of cross-talk a number of subscribers having pairs in a common cable, but this proved a complete failure. I agree, however, that in some cases, dependent upon the type and state of the cable, cross-talk might be appreciable.

Mr. Marris asks what power per loud-speaker is the usual figure on audio systems. If he means what power I feel should be allowed on normal strength, the answer is about 0.5 watt.

I can remove Mr. Lee's fears about Post Office technicians not being interested in the suppression of interference from electrical appliances.

Mr. Maskell is incorrect in thinking that the demonstration which I gave was an engineer's conception of quality.

The views of a very large number of non-technical listeners were obtained and there was general agreement that the quality was excellent. A frequent comment by the listeners was that the quality of speech was such as enabled them to hear without effort. It is true that in a few cases listeners preferred a restriction in band width.

Most of Prof. Marchant's objections to wire broadcasting are dealt with in the text of the paper. There is little doubt at all that if the success of radio broadcasting and wire broadcasting depended upon quality, the wire broadcasting system would inevitably supersede the radio system. Prof. Marchant ignores this question of quality and rather evades the fact that in many cases a radio service costs as much as a wire-broadcasting service. Also, in the event of damage to the cable network a much smaller number of subscribers are likely to be affected than if a radio transmitting station broke down.

I agree with Mr. Mercer that oil-impregnated cables have a somewhat higher attenuation than dry-core air-space paper-insulated cables of the same dimensions, but in an audio system of distribution the difference is not such as to be serious. The attraction of the impregnated cable is its greater reliability. The puncturing of the lead sheath would not normally put the service out of action.

Mr. Blackburn refers to the additional loss due to mismatches occasioned by changes in the gauge of wire. Actually in practice the wires between exchanges and subscribers' premises have not the large number of changes in gauge which he appears to visualize, and no great difficulty has been experienced from this cause. He also mentions a real difficulty in the need for co-operation between the Post Office man and the radio service man.

The question of the loud-speaker characteristic is a controversial one. It is, however, significant that in the vast majority of cases where opinions have been taken the listener's preference has been for the type of loud-speaker described in the paper.
